Beryllium CCOS Grinding Phase I SBIR Summary

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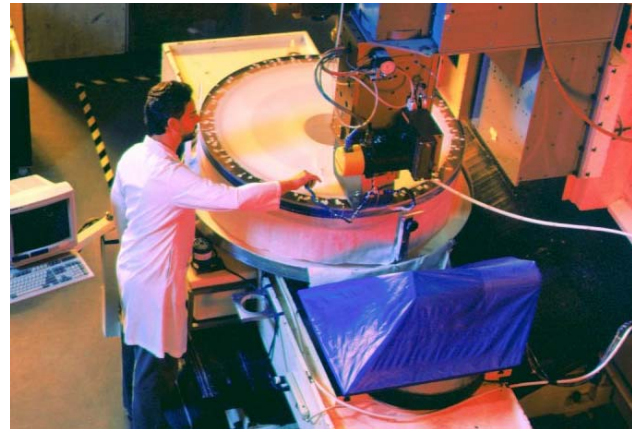
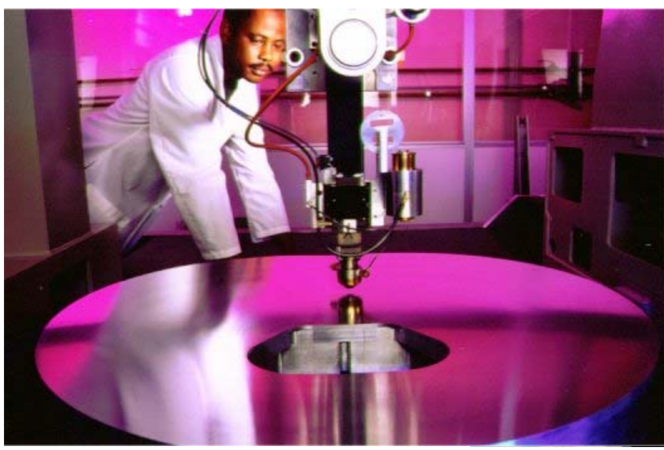
Tinsley Aspheric Fabrication Process Four Core Technologies

Precision Machining



CCOS

Surfacing

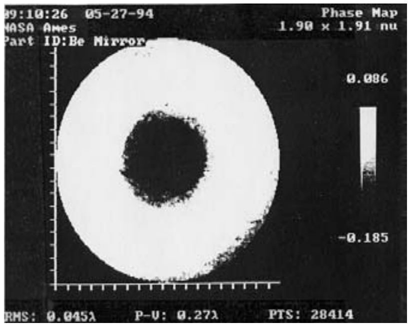


Profilometry

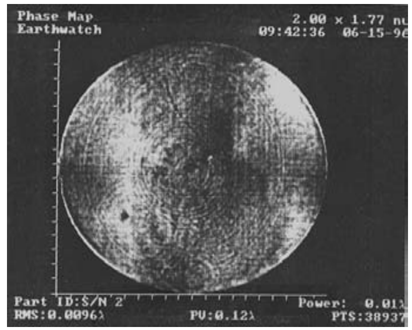
Microscopy & Phase Measuring Interferometry

Metrology

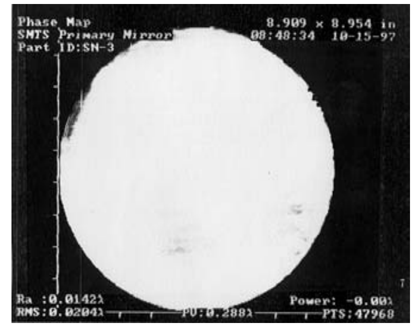
Tinsley CCOS Processes Demonstrated on Numerous Bare Beryllium Flight Mirrors



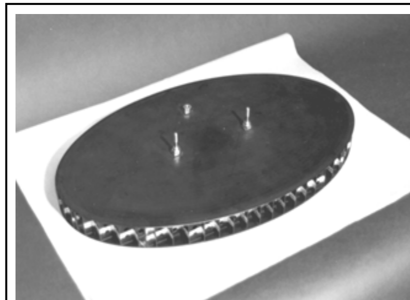
NASA Ames Demo Mirror
- 0.5 meter diameter
- 28 nm RMS



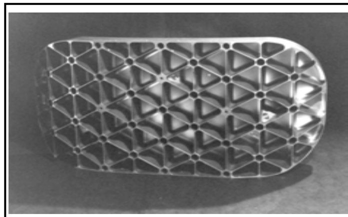
Earthwatch
- 0.45 x 0.3 meters
- 6 nm RMS

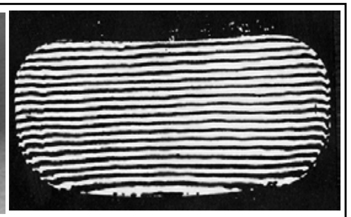


SMTS
- 0.25 meter diameter
- 12 nm RMS

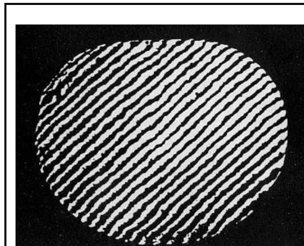


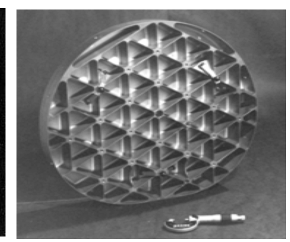
TIR
- 17 nm RMS 0.45 x 0.3 m
- Figured to < 5 mm of edge



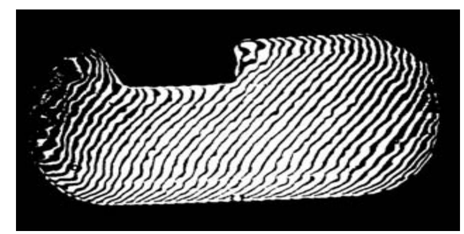


GSTS (M3)
- 0.75 x 0.37 meters
- 39 nm RMS
- Figured to < 5 mm of edge





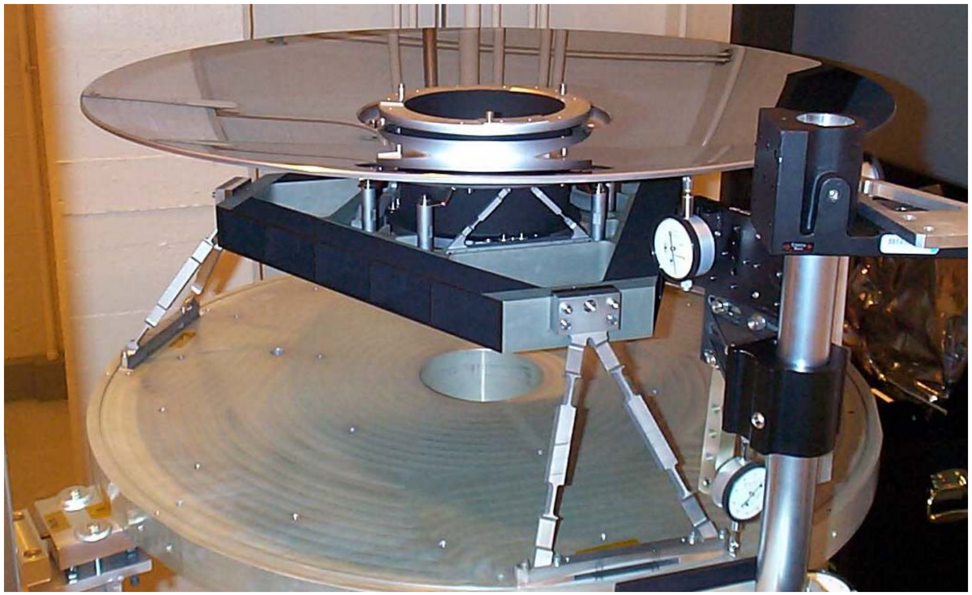
GSTS (M1)
- ~0.5 meter diameter
- 15 nm RMS
- Figured to < 5 mm of edge

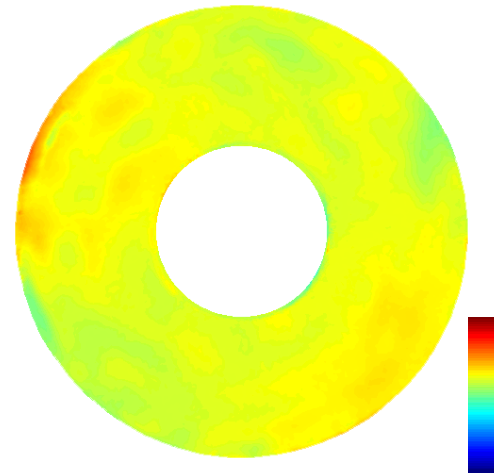


FEWS
- 80 nm RMS
- Figured to < 7 mm of edge

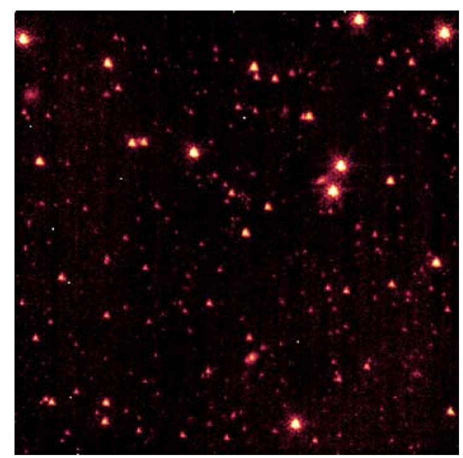
- Tinsley has demonstrated the ability to successfully finish bare beryllium optics on a number programs
- CCOS process suitable for flats, spheres, and aspheres

Tinsley Beryllium Mirror Experience: SIRTF





Cryo null figured for operation at 20 K
• 67 nm rms surface figure

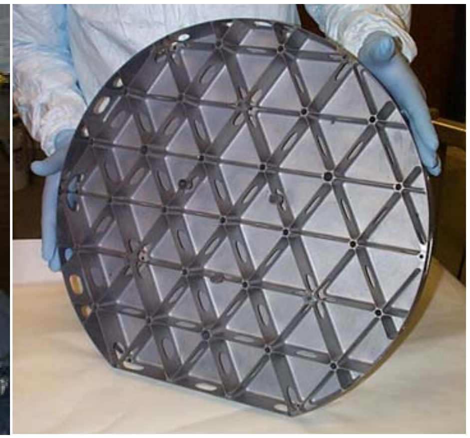


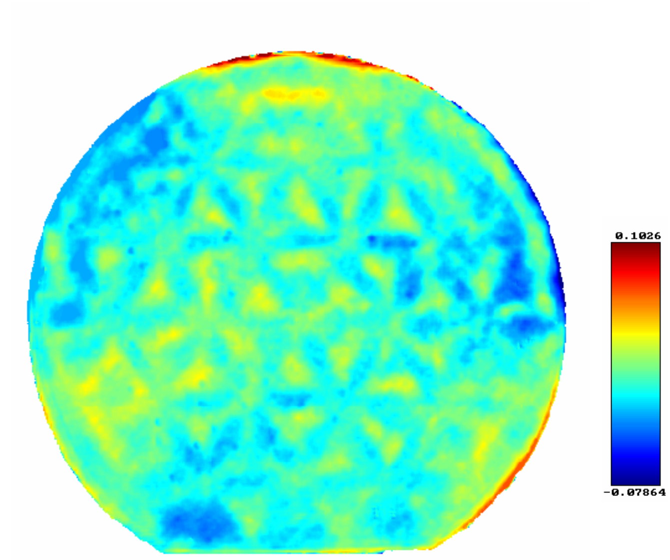
IRAC image through SIRTF telescope

SIRTF Primary Mirror

- 85-cm diameter
- I-70 Beryllium
- F/12 On axis hyperbola
- Double arch back design
- August 2003 Launch

Tinsley Beryllium Mirror Experience: SBMD (Sub-scale Beryllium Mirror Demonstrator)





	Key Specs	Test Results
• Areal Density	< 11kg/m²	< 9.8kg/m²
• RMS figure (@20K)	25nm	9.1nm
• RMS Mid-freq (1-10cm)	12nm	7nm avg
• RMS surface roughness	4nm	4nm avg
• Operating temperature	20K	20K

Test using IPI interferometer After cryo-null figuring Mirror Mounted at 20K

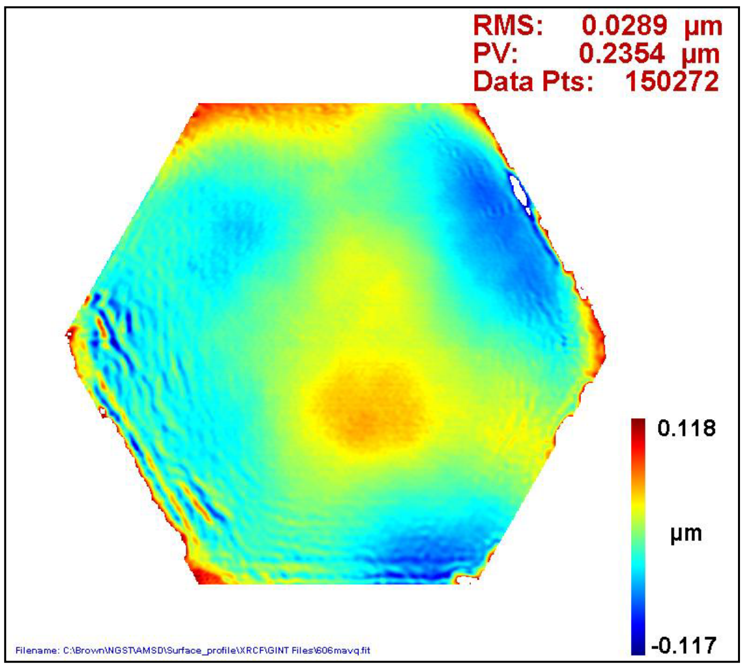
- Full CA Error: 9.5nm rms
- Mid-freq error : 7nm rms

- 0.5 meter diameter pathfinder for JWST
- Spherical lightweighted O-30 Beryllium substrate
- SBMD Cryo null figured to <10 nm RMS at 20 Kelvin

Tinsley Beryllium Mirror Experience: AMSD (Advanced Mirror System Demonstrator)

<u>AMSD Key Parameters</u>

- 1.2 meter bare Be aspheric mirror
- Off axis parabolic segment
- Ultra lightweight (9.8 Kg/m^2) O-30 substrate
- 29 nm rms figure accuracy demonstrated
- Mirror to be cryo null figured (20K)
- ROC = 10,013mm $\pm$ 1mm



AMSD Demonstrated to 29 nm RMS

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SBIR Objectives

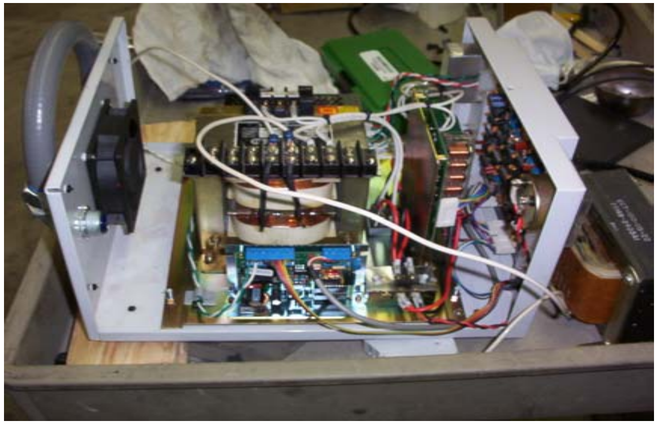
- CCOS of Bare Beryllium Aspheric Optics
  - NASA Contract #NAS8-03036
  - TPOC: Dr. Phil Stahl, NASA/MSFC
- CCOS grinding and polishing of bare beryllium has been successfully demonstrated by Tinsley for a number of space-based telescope applications
  - SBMD, AMSD, SIRTF, FEWS, GSTS
- Grinding of bare beryllium is made difficult by the hardness and brittleness associated with beryllium
- Electrolytic In-Process Dressing has been applied successfully to metal surface grinding
  - In-situ tool dressing improves grinding efficiency
- ***SBIR activity conducted to apply similar in-situ tool dressing techniques to improve the material removal rate and uniformity associated with the CCOS grinding of beryllium***
  - ***Potential Process Improvements: (1) improved grind material removal rates; and (2) improved uniformity of grind rate over time***

Review of Phase I Activities/Issues

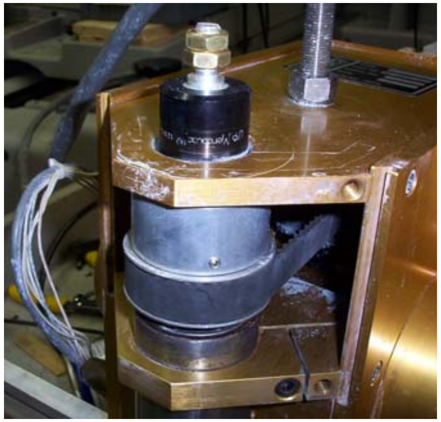
- **Selection of baseline tool dressing approach**
  - Electrolytic In-Situ Dressing versus EDM based approach
  - EDM based approach selected to optimize material erosion rate
- **Grinding tool material selection**
  - Both dressing approaches lend themselves to conductive, metal grinding tools
  - Softer, resin based tools more forgiving from an optical fabrication standpoint
  - Copper resin selected as electrically conductive, but mechanically elastic grind tool
- **EDM fluid selection**
  - Dionized water used as EDM fluid for Phase I demo work
- **Existing CCOS machine tool has been modified to accept in-situ EDM tool dressing components**
  - Output from a portable EDM unit modified with a stepdown transformer
  - CCOS grinding spindle modified to accept in-situ dressing components
    - Graphite and brass electrodes used for Phase I tests

Phase I Hardware Photos

Portable EDM Unit



Stepdown Transformer

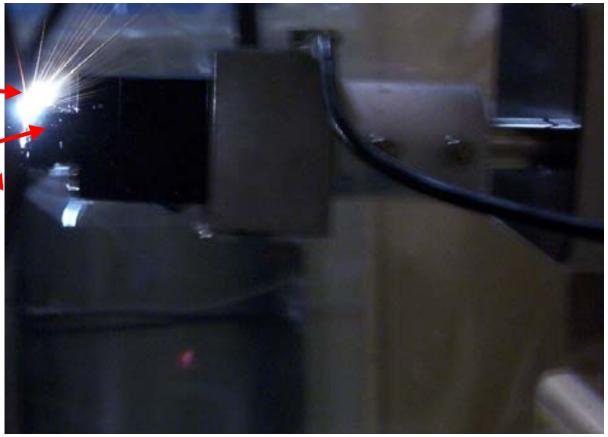


Modified CCOS Spindle

EDM discharge

Graphite Electrode

Grinding Tool

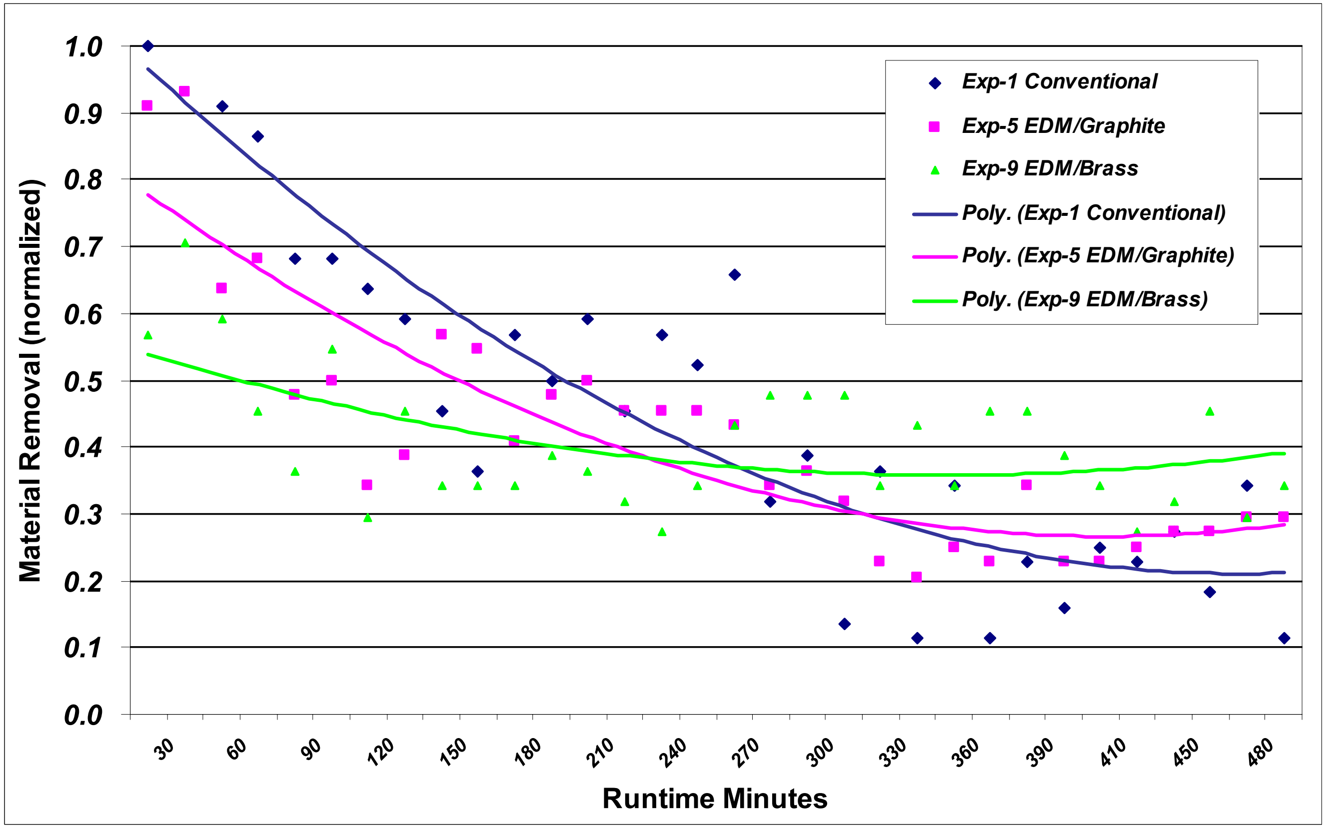


EDM dressing of copper/diamond grinding tool with graphite electrode

Phase I Demonstration Samples

- (6) 150 mm diameter I-70 Beryllium discs processed for experimentation
  - (2) conventionally CCOS ground
  - (2) EDM assisted (copper/diamond tool, graphite electrode)
  - (2) EDM assisted (copper/diamond tool, brass electrode)
- Processing done to look at material removal rate, and the uniformity of the material removal over time

Phase I Results



- Both EDM experiments show an initial reduction in material removal rate compared with conventional CCOS grinding
  - Graphite ~20% reduction; Brass ~40% reduction
- Both electrodes show a more uniform material removal rate over time
  - Total material removal profile (averaged over the 500 min runtime shown) for EDM assisted grinding is ~11% less than conventional CCOS processed samples

Phase I Summary – Phase II Program Plan

Phase I Summary

- Brass electrode EDM work shows some conflicting results
  - More uniform material removal profile could provide a dramatic improvement in CCOS grind/polish correlation and surface convergence
    - Particularly important for large aperture pieces such as JWST
  - Reduced material removal rate is problematic and not consistent with the positive results which have been experienced in the surface grinding of beryllium with assisted dressing techniques

Phase II Plan

- Examine additional process variations in order to build off of our Phase I results
  - Target improved material removal rate while improving the linearity of the material removal over time
  - New electrode materials, cutting materials, EDM fluids, application of micro-EDM, modify CCOS processing parameters, etc
- Apply these newly developed processes to manufacture a bare beryllium aspheric demo mirror
  - Compare processing time with conventional CCOS figured mirror